Fabrication of a uniform large scale array of X-ray microcalorimeters for the X-IFU instrument on Athena

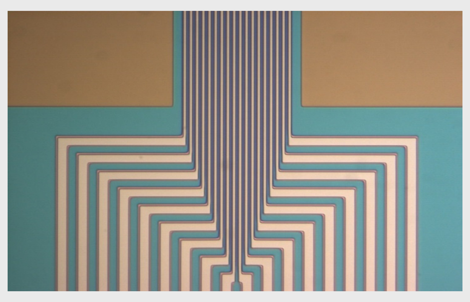
M.L. Ridder[1], K. Nagayoshi[1,], M.P. Bruijn[1], P. Khosropanah[1], L. Gottardi[1], H. Akamatsu[1], J. van der Kuur[1], J.R. Gao[1,2]

[1]SRON Netherlands Institute for Space Research
[2]Kavli Institute of Nanoscience, Delft University of Technology

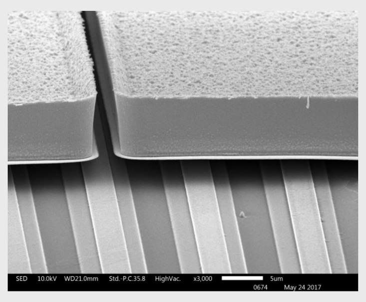
Abstract

Future spaced-based imaging X-ray spectrometers, such as the X-IFU (X-ray Integral Field Unit) instrument on ESA's Athena mission, will be based on large format arrays consisting of more than 3800 Transition Edge Sensor (TES) microcalorimeters. We present an optimized lithographic fabrication route that enables the realization of such large format arrays of microcalorimeters. We improved on process steps concerning the X-ray absorber, the stripline wiring system and the silicon grid support structure. We have developed an electroplating process for the fabrication of free standing cantilevered X-ray, which leads to a uniform absorber film thicknesses over the large array. We also developed and fabricated high density Nb/SiO_2/Nb striplines to wire a 4000 pixel array. We report on the optimization of the deep reactive ion etching step to form the silicon grid structure, which allows the production of uniform silicon grids accommodating an array of 4000 TES pixels.

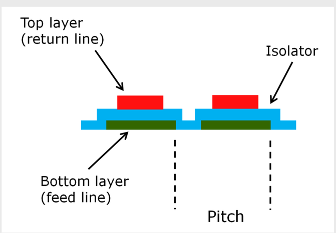
High density Striplines



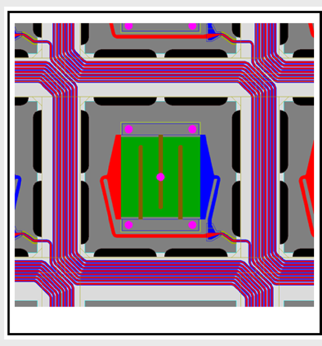
Topview of a bundle of striplines (optical microscope)



SEM image of a microstripe line



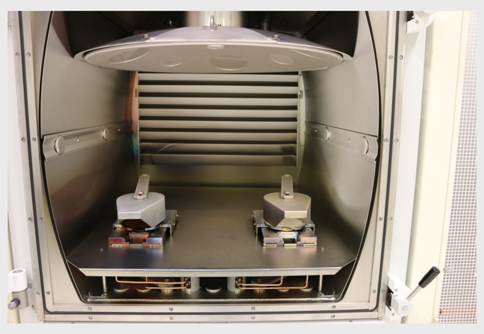
Schematic cross section of a stripline (left). Our process route is based on the following process steps
- Patterning of the bottom Nb layer (green)
- Coverage of SiO2 isolator
- Alignment and patterning of the top Nb layer.



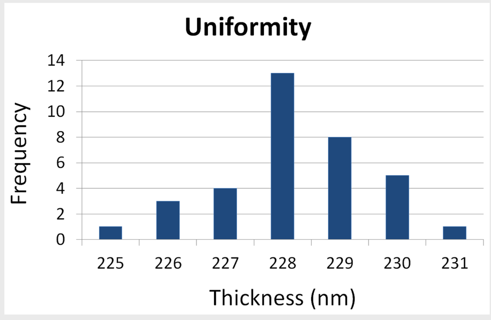
Pitch (µm)	18 lines (µm)	Si bars (µm)	Pocket size (µm^2)	TES size (µm^2) max
2.8	50.4	52	198 x 198	132 x 132
3.2	57.6	60	190 x 190	126 x 126
3.6	64.6	66	184 x 184	120 x 120
4	72	74	176 x 176	112 x 112

To wire a X-IFU 4000 pixel array, a bundle striplines is needed that consists of 18 line pairs. With our process route we are able to fabricate striplines with 3.2 micron pitch. For a pixel design with 250 µm pixel pitch this means that the TES size should not exceed 126 x 126 μm^2.

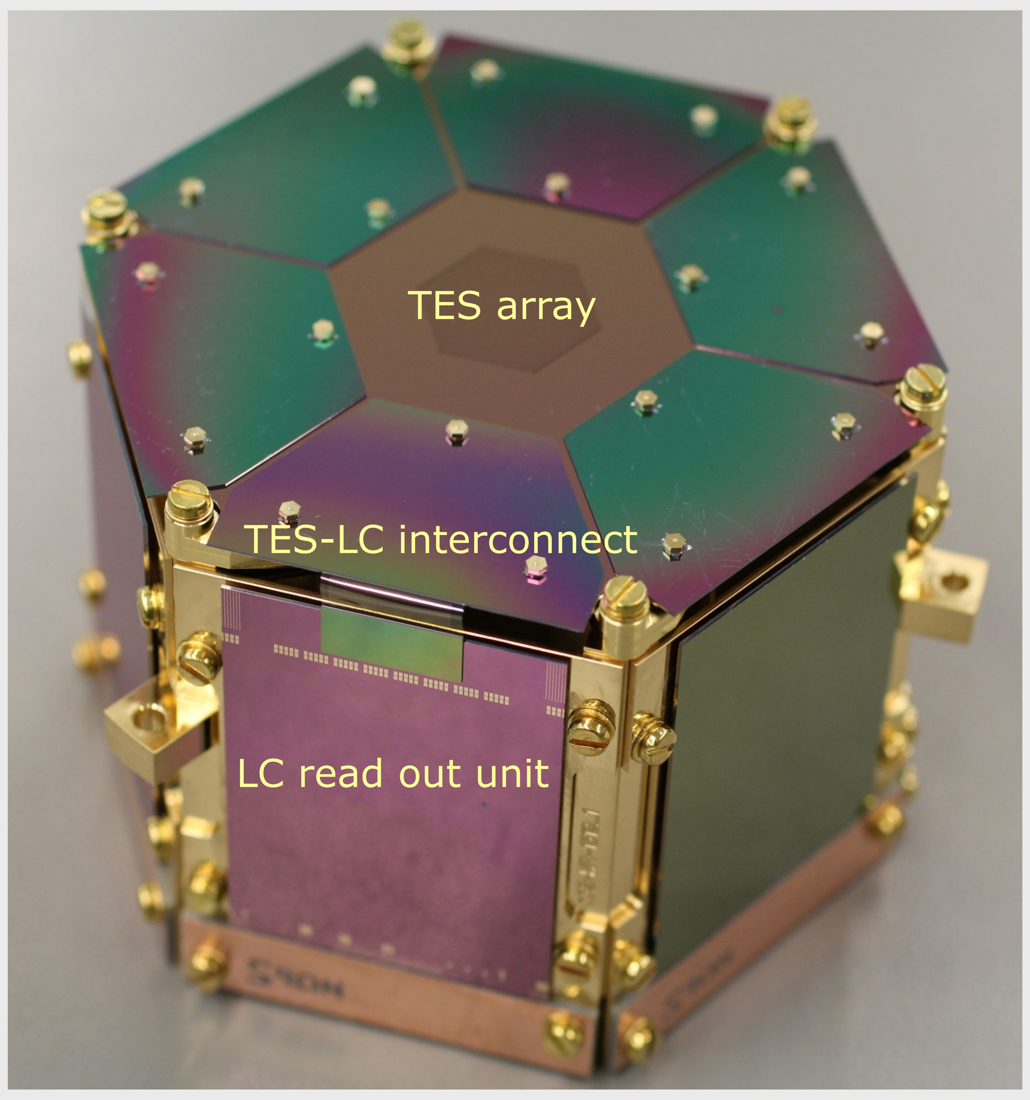
Uniformity TiAu TES bi-layer



BAK 760 Dual Beam EB-PVD Evaporator gives full control of the TiAu deposition

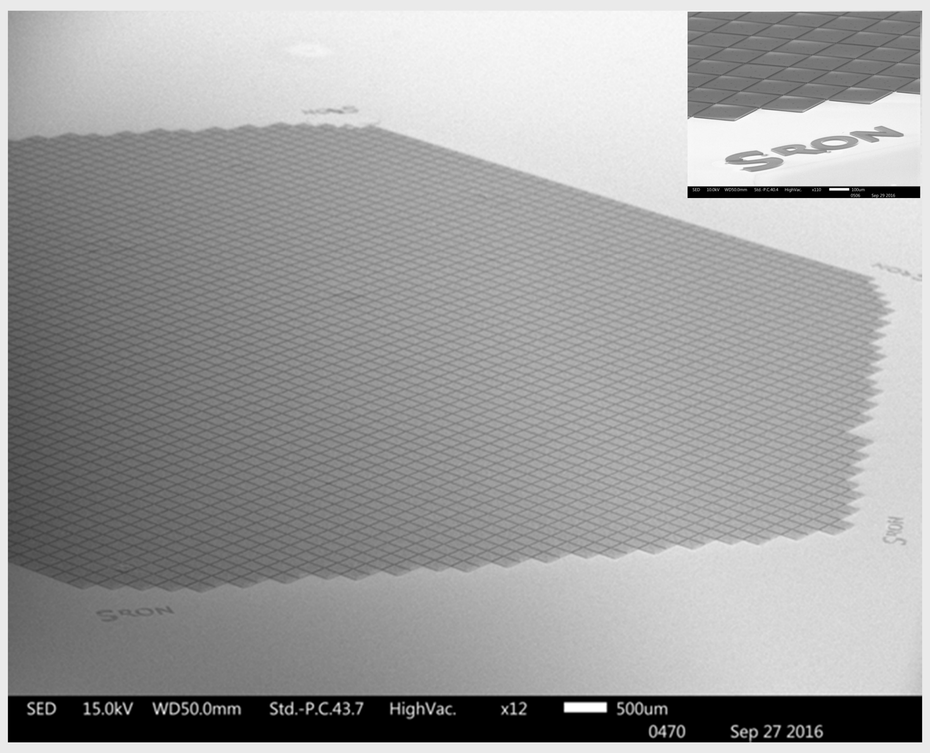


Thickness uniformity over a 4 inch wafer. Standard deviation is better than 1 %

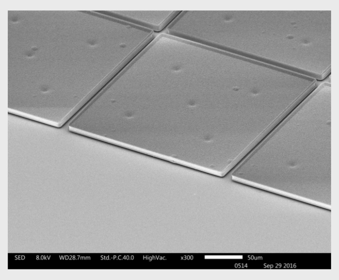


Focal Plane Assembly detector unit mechanical prototype as realized under ESA GSTP

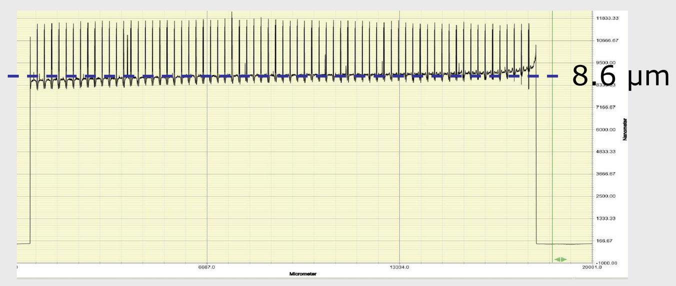
Electroplating 4000 Absorbers



SEM image of an array of 4000 AuBi multilayer mushroom shaped absorbers

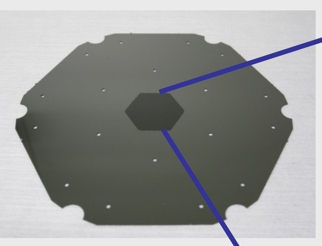


Detail of the absorber hat supported by five pillars

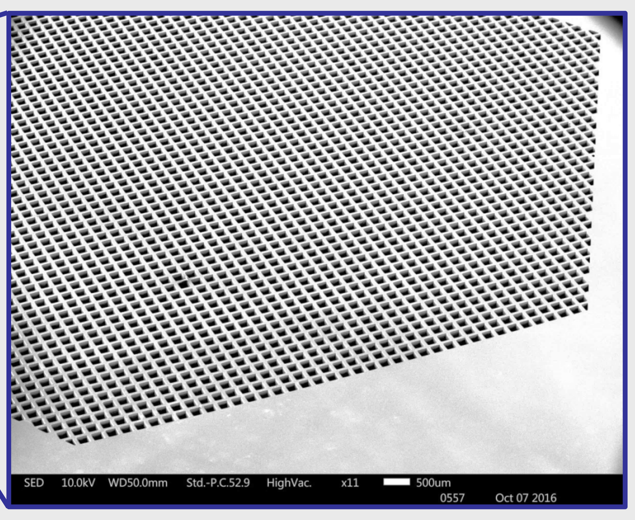


DEKTAK scan over the absorber hats. Nominal thickness of the Au/Bi is 3.5/ 5.0 µm. Measured total thickness is 8.5 - 8.7 µm

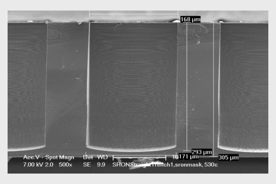
DRIE etching Si support structure



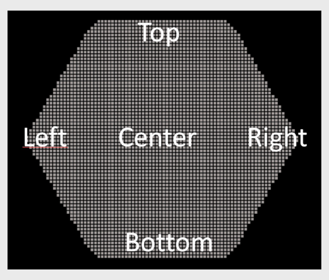
Hexagonal chip with the Si grid



SEM Overview of the DRIE etched grid



Cross section of a DRIE etched pocket

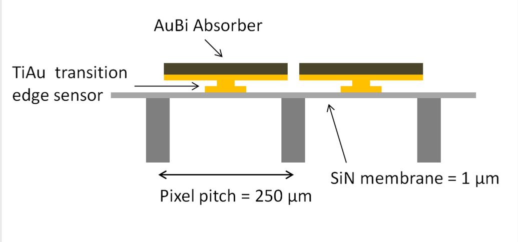


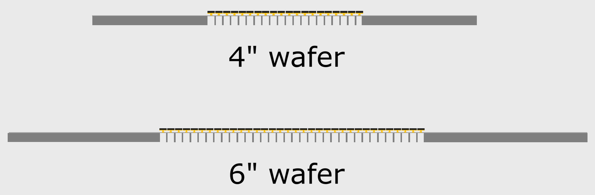
	Pocket size Vertical (µm)	Pocket size Horizontal (µm)
Top	164,1	164,9
Center	164,5	164,5
Down	164,9	165,3
Left	163,9	164,5
right	164,9	164,9

Measurements of the pocket size in two directions shows excellent uniformity of the pockets within the grid

Larger arrays -> larger wafers

Future space-based X-ray astronomy missions are likely to have increased demands in collecting area. This will lead to detectors arrays consisting 10,000+ pixels. The SRON clean room facilities are suitable for 6 inch wafers processing.

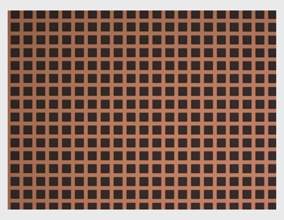




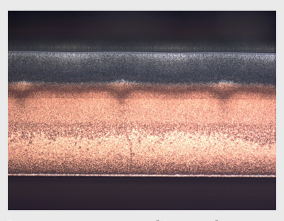
Heat sink layer

A Copper cooling layer on the backside of the grid and on the sidewalls of the pockets is required to improve temperature stability of each pixel.

Tilted position of the wafer in the evaporator

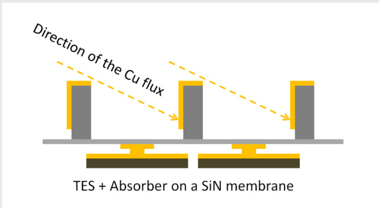


Copper cooling layer on a backside of the grid



Copper cooling layer on the side of a Si bar

Schematic of the deposition of the backside heat sink. The Si bars shadow the directional flux. By using the proper angle undesired deposition on the backside of membranes can be realized.



Conclusions

Future spaced-based imaging X-ray spectrometers will be based on large format arrays consisting of more than 3800 pixels. SRON has the facilities for the production of these large arrays. We also optimized our lithographic fabrication process to enable the production of uniform large TES arrays. The SRON fabrication team is ready for the (X-ray) future.

Acknowledgements

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Marcel Ridder, SRON Netherlands Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, the Netherlands, (phone: +31-8887775600; email: m.ridder@sron.nl)

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SRON Netherlands Institute for Space Research www.sron.nl

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